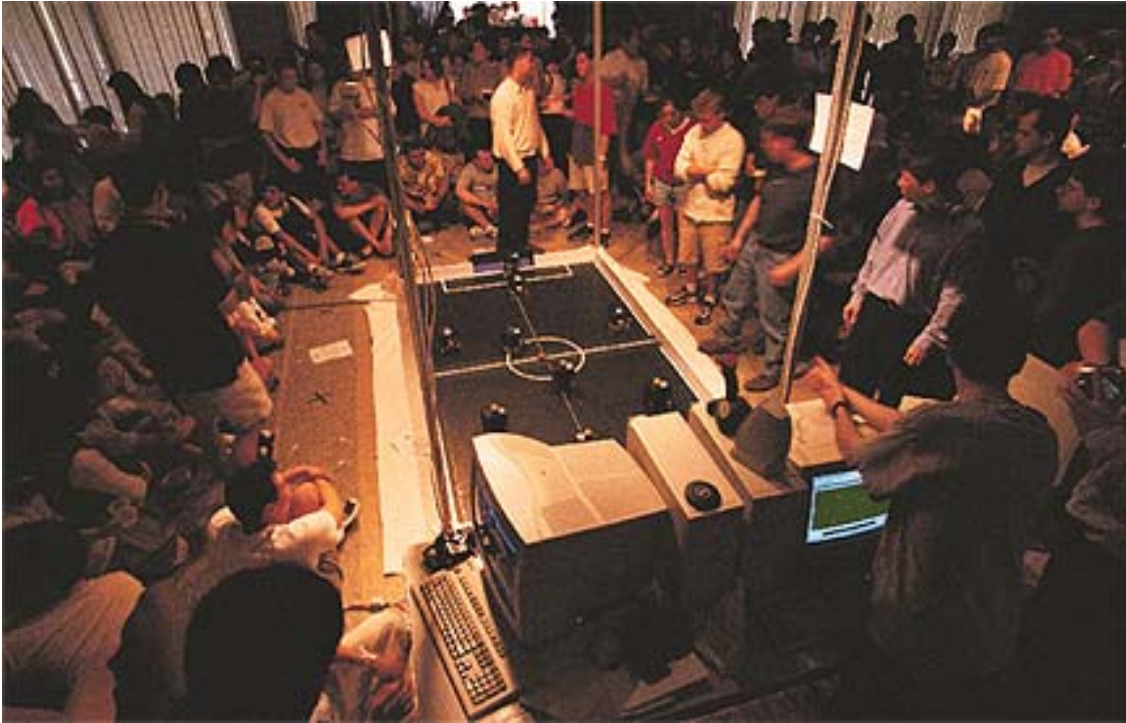


# The story of Cornell's 'Big Red' team at RoboCup

*As reported by Prof. Raffaello D'Andrea*



*The whistle blew at 2:00 PM today, and before 10 seconds had elapsed, Robotis, the 1999 Mirosoft champions (Mirosoft is the other international robotic soccer league) and heavy favorites to win the 1999 RoboCup competition, had put one past the Big Red Bots and were up 1-0. But before going any further, some background is in order...*

## **Monday, July 26<sup>th</sup> 1999 2:30 PM**

Andrew, Aris, JinWoo, Lars, and Tom arrive in Stockholm, after having flown the red-eye from Ithaca. Even though the team is tired, spirits are high as the Cornell team looks forward to 2 full days of testing, calibration, and set up before its first game on Thursday. A minor complication arises when the team finds out that ALL but one of the checked pieces of luggage did not arrive in Stockholm; this is not too much of a concern, since the British Airways staff informs us that luggage is delayed from Heathrow all the time.

## **Monday 10:00 PM**

Three flights later, the luggage still has not arrived. After more than one hour on the phone trying to get the problem resolved, I get cut off due to the strict 10:00

PM closing time at British Airways. We are assured that the luggage will arrive first thing in the morning.

### **Tuesday 8:00 PM**

We meet for breakfast in the hotel at 8:00 am. The luggage has not arrived, and in fact, we receive some disturbing news: British Airways has no clue as to the whereabouts of our luggage. They cannot track it; it is as if it never existed, except for our lost baggage claims and some baggage tags on the back of our tickets. A slight panic overtakes us; even though we carried the robots and camera with us on the plane, the custom video cables, the custom camera power supply, the custom battery packs, and all of our tools are missing. We prepare for the worst and start making contingency plans....

### **Tuesday 3:00 PM**

One of the bags has arrived; we now have some tools, but most of the important equipment is still missing. Lars and JinWoo set out to test the robots with our limited resources while the rest of us work on the rest of the problems. JinWoo is wearing the blue and purple British Airways socks, which clearly do not match his beige shorts. Lars opts to not wear socks at all; the Cornell team looks pretty ragged, and the fact that we are asking the rest of the teams for spare components does not help matters.

Aris and Tom are calling the United States and Canada to get the pinouts and specs for the Sony camera and power supply, and the Genesis Frame Grabber; the Sony distributor in Sweden has never heard of our camera, and Matrox Genesis does not have a presence in Sweden. Our phone bill is getting large.

Andrew and I are scrambling to find an electronics distributor so that we can buy the minimum 100 rechargeable, high capacity batteries we need for the competition, and the other hardware for constructing the video cables. We really don't know where to start, except the phone book (there are no Swedish teams in the competition). After several phone calls, we ask the receptionist at the hotel which of the listed 50+ distributors are near to us to narrow down the search. The photocopier repairman overhears our conversation and points us to "the best shop in Sweden for electronics!" A break! We call them, and as our luck would have it they close at 4:00 PM.

It is 3:45. Andrew and I are racing through the streets of northern Stockholm, trying to find ELFA. Not including speeding, U-turns, and driving on the curb, I break about 5 other laws. Andrew looks a little bit nervous...

After some lucky turns, we get to ELFA at 3:57. They are still open. We rush to the counter, explain our situation, and they keep the rather large store open for us until 5:00; in this time, we are able to purchase all of the cable and connectors

we will need for the camera, frame grabber, and batter packs, but we are only able to purchase 12 of the 100 batteries we need (the rest are not in stock). We are told that their main warehouse has another 39 in stock, and that we can pick them up tomorrow at 7:00 AM. It is possible to run one complete game with one set of batteries, and besides, we have no choice...

### **Tuesday 5:00 PM**

We are informed the luggage with the battery packs has been found, and that it will arrive by Wednesday noon. The other luggage is still AWOL. This is a big break; Aris and Tom have managed to obtain the pin outs and specs, and Lars and JinWoo have pretty much checked out all of the robots with the lone power supply at our disposal.

### **Tuesday 10:00 PM**

Even though we received conflicting pin outs from two Sony techs in the US, one of the configurations is ruled out as "improbable", and we connect up the camera for the first time with our home-made cable and power supply. It works. Tom begins the painstaking video calibration process, even though extra equipment will have to be made or purchased to mount the camera at the correct height; most of this work will have to be redone, but we need to be sure that the system can be calibrated with the poor signal quality we are receiving due to the home-made cables we are using.

We use the 12 purchased batteries to make a battery pack and we begin to test the robots. Another late night.

### **Wednesday 12:30 PM**

After more than one hour on the telephone with British Airways, we find out that the luggage with the batteries is lost again. They do not know where it is, and cannot tell us when it will arrive; they do tell us, however, that the luggage with the video cables has arrived, and that it will be delivered to our hotel. Lars and I drive to the ELFA warehouse to purchase the remaining 39 batteries, but they are sold out. We are forced to purchase 84 under-capacity batteries, which we hope will work in the competition.

### **Wednesday 8:00 PM**

After constructing the new battery packs, we call British Airways and find out that all of our luggage has just been found. It arrives at our hotel at 10:00 PM. We now have 12 hours before our first game, against the winners of Mirosoft, and we have not tested the system, let-alone many individual components. It's going to be another long night...

### **Thursday 2:00 PM**

The whistle blows at 2:00 PM today, and before 10 seconds has elapsed, Robotis, the 1999 Mirobot champions and heavy favorites to win the 1999 RoboCup competition, has put one past the Big Red Bots and are up 1-0. There is clearly something wrong with our system, our goalie never reacted to the streaking player. We use up one of our precious time outs, and determine that the reason for our inactivity is a false ball reading from the vision system. Robotis has placed a chair behind the goal, which cast enough of a shadow on the goal area to fool our vision system into registering an incorrect position for the game ball. We ask them to move the chair, and the game resumes.

The game styles are vastly different. The Cornell team has an incredibly strong defense. The goalie is unbeatable, and the defending players attempt to block the Robotis attacks at every turn. The Cornell offense is conservative, and makes charges only when it is safe to do so. Robotis, on the other hand, is an attacking machine; the 4+ years of experience shows, and we are being constantly being barraged by shots. Robotis, a company specializing in video and robotics equipment, is quite an opponent. Our strategy, however, is extremely effective, and our clearing passes and strategy flawless. We score a goal half way through the first period, taking advantage of a good offensive situation. The bleachers are full, and the spectators are clearly cheering for the underdog Cornelian, the team that has never played against another team before, and that has had only 12 hours to set up their team, instead of the 60 for all of the other squads.

3 minutes later, Cornell scores again. Robotis is all over Cornell, but the Cornell strategy pays off: excellent goaltending, strong defense, and opportune attacking. The half ends at 2-1 Cornell.

The second half is a repeat of the first half; Robotis swarms Cornell, but Cornell holds on. The final whistle blows, and the score remains Cornell 2, Robotis 1. There is an uproar from the crowd; many veterans tell us that this is one of the best games of robotic soccer ever played. The top contenders come and congratulate us, and pepper us with questions. The Swedish media interviews Andrew and takes pictures. JinWoo is ecstatic, having participated in Mirobot in Korea before and finally getting revenge on the winning team. Aris, Lars, and Tom look totally worn out after being at the helm for over 1.5 hours setting up the robots between stoppages in play and between time outs.

Our next game is at 10:00 tonight ...

## **Sunday August 1**

We played the AllBotz (New Zealand) at 10:00 PM Thursday. Final score Cornell 33, New Zealand 0.

We played 5DPO (Portugal) at 7:00 PM on Thursday. Final score Cornell 8, 0.

We have made it to the quarterfinals. We are scheduled to play against Singapore on Monday, August 2nd.

We have just found out that the final will be telecast on Swedish television, and they are forecasting 1 million viewers!!! Two well known commentators will be covering the final (one of them is a member of the Swedish national soccer team). We have a good chance to make the final.

More details on Monday...

## **Monday 2:00 pm**

Cornell 20, Singapore 1.

The game was quite lopsided, as the score indicates. Our players performed remarkably well, although we did incur one yellow card for rough play. This is inevitable, in my opinion, due to the strength of our robots; we always looked like the aggressors in a collision, even though our collision avoidance was vastly superior to our opponent's. In addition, Singapore used an illegal placement of markers, and as a result, our vision system could not properly determine their orientation. As a result, they scored their goal on a free kick, which we probably would have saved if their marker had been in the correct position. The main reason the committee decided to let Singapore compete with the illegal markers was that we were considered the heavy favorites for this match, and that enforcing compliance would have put too much hardship on the opponent.

Cornell advances to the semifinals. Next game, Tuesday, 2:00 pm.

## **Tuesday 8:00 am**

In the other quarter final match of our division yesterday, Lucky Star (Singapore) beat one of the tournament favorites and defending champions Carnegie Mellon (USA) 8-0. This was perceived to be an upset, but Lucky Star has been a strong team throughout the tournament. They are the current Pacific Rim champions; they will be our opponents this afternoon.

In the other division, Robotis (Korea), the defending Mirosoft champions beat Roboroos (Australia) 13-0, and Fu-Fighters (Germany) beat Rogi (Spain) 11-0.

After the victory last night, the Cornell team spent the evening studying tapes of the competition for the upcoming games. Some of the strategy changes we are making this morning include a new penalty shot defender role to cope with the very fast Lucky Star robots, and trying some new set plays.

## **Tuesday 1:00 pm**

Cornell vs. Lucky Star (Singapore)

*Pre-game:* We made several changes to our AI code this morning and increased the speed and acceleration of our robots to better cope with the fast Lucky Star robots. We also fixed some minor bugs that we discovered while reviewing videotapes of the previous game.

*1st half:* Cornell took the lead approximately 2 minutes into the first half; some good passing and a timely kick found the Singapore woefully out of position for the first mark.

At approximately the 5 minute mark, Cornell netted its second goal on a rush from our forward; a clear line of sight between the ball and the goal was spotted by our robot, which decided to accelerate at maximum speed into the net, with the ball. Cornell 2, Singapore 0.

Between the 5 and 7 minute marks, the Cornell team received 3 warnings and one yellow card; our higher speed settings have caused our players to sometimes skid slightly out of control; but more importantly, to push the other robots around in 50-50 situations. Due to our more powerful robots, we looked like the aggressors and were thus penalized. We substituted Ray for Major Tom (the player with the yellow card) to prevent a red card and mandatory expulsion.

At the 8-minute mark, Singapore nets a goal by exploiting a mechanical oversight on the part of the Cornell team; there is a space approximately 1 inch above the base of the goalie, which just barely accommodates a golf ball. During one of the Singapore strikes, the ball crashes into our goalie, is pushed above the bar by the Singapore striker, and rolls into the net. Cornell 2, Singapore 1.

At the 9-minute mark, Singapore scores another goal on a nice one-two pass combination. Cornell 2, Singapore 2.

*Half Time:* Cornell decides to adopt the timeless sport philosophy "play with what got you there" and decides to change the gains back to the ones used in the previous games. This is done for two reasons; the first is to avoid a red card and mandatory expulsion of one of the robots. The second is to give the robots more control in passing, which was somewhat degraded from previous games. This

decreased passing performance could of course be due to better opponent defense, but the team agrees on the move.

*Second Half:* The whistle blows, and within one minute of play it is clear that the Cornell team plays much better with the reduced gains. The control and passing is back. At the two-minute mark, Cornell is awarded a penalty shot, which is shot wide.

At the twelve-minute mark, Cornell takes the lead on a direct shot from the side. Cornell 3, Singapore 2.

14 minute mark: Cornell 4, Singapore 2.

16 minute mark: Cornell 5, Singapore 2.

17 minute mark: Cornell 6, Singapore 2.

The final whistle blows, and Cornell advances to the RoboCup Final.

In the other semifinal match, FuFigthers (Germany) upsets Robotis (Korea) 5-3. The German team will be a very tough foe for the American squad. Game time tomorrow is 2:30 PM.

### **Wednesday 1:00 PM**

We are about one and a half hours away from game time, and yes, we are extremely nervous. We are making the final calibrations and preparations, and making sure that nothing is being overlooked. The system is quite complex, and extremely interconnected. We have to make sure that all of the subsystems are fully operational in order to achieve the maximum performance that our robot team is capable of.

Tom is fine-tuning the vision system, and making sure that it is as robust as possible to changes in the lighting conditions (we are expecting quite a few film crews, which will undoubtedly disturb the existing conditions). Aris is testing some new defensive code he wrote this morning that should render the powerful kicking mechanism of the FU Fighters completely ineffective; the idea is to have the defensive players strategically position themselves to simultaneously mark their offense AND guard any open paths to the net. Lars is also testing the goal-keeper role to make sure that it will be capable of withstanding their 6 m/s + kicks; our goalie has only allowed four goals in this tournament, one of which was a glitch due to a shadow on the field, another on a penalty shot by a player with illegal markings (which prevented us from correctly establishing its orientation), and the third a slight mechanical oversight on our part. In other words, our goalie AI has only been beaten once. The work Lars did over the summer has certainly paid off! Andrew, AKA "McGiver", is fine tuning the robots and making sure that

all of the mechanical and electrical systems are fully operational; he must do this with the occasional banter from the Cornell team, teasing him (in fact complimenting him) about the fact that he could probably build a robot out of paper clips, scrap wire, lemons, and dried up leafs. Jin Woo and I are making sure that no system level issues are being overlooked, and that all of the pieces are coming together.

The game room is quite small, approximately 600 square feet. The only people allowed into the room are the two teams, the officials, the RoboCup organizers, the media, and a handful of spectators. The game will be broadcast in the 1000+ seat auditorium in the Stockholm Conference center on a 20 foot by 20 foot screen, with two color commentators; Tucker Balch, one of the RoboCup organizers, and a local sport commentator for the Swedish spectators.

### **Wednesday 2:00 PM**

Prof. Raul Rojas (FU Fighters) and I are asked to give a brief, 5 minute description of our teams to the spectators in the auditorium before the game. I stress that the crowd should look for three things from our robots: very strong defense, sophisticated trajectories, and emergent passing and shooting behavior. Rojas stresses the FU Fighters kicking mechanism, which has propelled them to the final. Raul and I exchange School emblems, and head back to the playing field.

### **Wednesday 2:20 PM**

The game is about to start, and Graham Chedd, the executive producer of Scientific American Frontiers (some of his other credits include co-founder of the PBS science magazine series Discover: The World of Science, he helped found the weekly science television series NOVA and became its first science editor, and he was co-creator of the PBS series Odyssey), is instructing his film crew to wire me up for the on-game comments. Graham is producing a new show on human inspired robotics, and from the suggestion of Prof. Manuela Veloso, the team leader of the defending champions CMU, decided to follow our team since the quarterfinals (good choice!!!). He is quite impressed by our team so far.

### **Wednesday 2:30 PM**

It is game time. The FU Fighters win the coin toss, and decide to kick off. We wait in slight trepidation for the kick-off, since we do not know if our goalie and defenders can cope with the powerful kick. Soon, we will find out. The whistle blows, and our robots accelerate to the ball and effectively block the shot. The ball quickly moves to their end, and it is clear to me, after only 10 seconds of

play, that we are going to win this match. Our robots are faster, more maneuverable, can navigate around obstacles, can pass the ball, shoot on net accurately, and essentially beat their robots to every free ball. Within one minute, Cornell scores its first goal. Cornell 1, FU Fighters 0.

The game continues for some time, and Cornell continues to score more and more goals. The outcome of the game no longer in question, it is just a matter of seeing if we can get a shutout. Our goalie is only tested once, but a formidable test it is. One of their defenders manages to get to the ball before our robots and propels the ball at over 6 m/s towards the corner of the net. Harry 2, our awesome goalie, moves to the precise location of the ball just as it reaches the net. The crowd is amazed, and in fact, so are we. It is at this point that we fully realize what we have accomplished in this competition; not only are we going to win the RoboCup, we have set a new paradigm for Robot Soccer. Just like Bobby Orr revolutionized the role of a defender in Hockey in the 70s, Wayne Gretzky the role of a center in Hockey in the 80s, and close to home, Pele the role of a forward in soccer in the 60s, Cornell has redefined the game with its playing style and performance. The whistle blows, Cornell 14 - FU Fighters 0.

Cornell is the winner of the 1999 RoboCup Small Size (F180) league.

## **Epilogue**

The awards ceremony took place at around 5:00 pm. In the other leagues, Carnegie Mellon (USA) won the Simulator cup, France won the Sony Legged Dog competition, and Iran won the Mid Size league.

Cornell and the Roboroos (Australia) had a friendly match at the request of the Australian Squad. After 10 minutes, the score was Cornell 6, Roboroos 0. Cornell pulled off three players to see if it could withstand a 5 on 2 barrage, and to test the goalie and defender roles. After 5 more minutes, the score remained 6 to 0. We are coming home!!!

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